

# Process Improvement and Optimization of Insensitive Explosive IMX-101

## 2012 Insensitive Munitions & Energetic Material Technology Symposium

\* Virgil Fung, Ben Schreiber  
BAE SYSTEMS Ordnance Systems Inc.  
Holston Army Ammunition Plant, TN

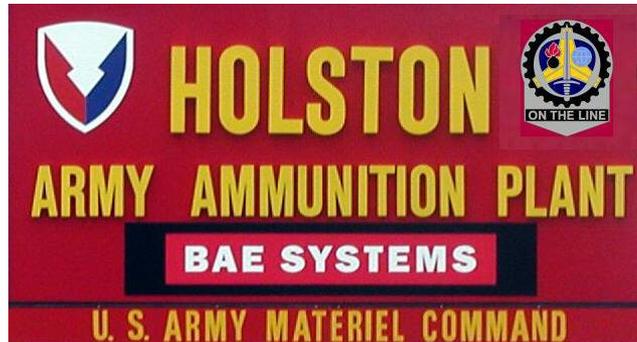
Charlie Patel, Philip Samuels  
U.S. ARMY PM-CAS  
Picatinny Arsenal, NJ

Paul Vinh, Xue-Ling Zhao  
US ARMY ARDEC  
Picatinny Arsenal, NJ



# Briefing Outline

- IMX-101 Explosive Overview
- Recent Manufacturing Achievement
- IMX-101 Process Improvement & Optimization
- Modernized Melt-Cast Explosive Manufacturing Facility at HSAAP
- Concluding Remarks
- Acknowledgements



# IMX-101 Explosive Overview

- An insensitive melt-pour explosive to replace TNT for Artillery Projectile Applications
- IMX-101 and all starting ingredients manufactured at Holston Army Ammunition Plant
- Exhibited superior IM properties and comparable performance over TNT in 155mm M795 projectiles



IM Test:	Fast Heating	Slow Heating	Bullet Impact	Fragment Impact	Sympathetic Reaction	Shaped Charge Jet Impact
155mm M795 (TNT)	III	III	IV	IV	FAIL	FAIL
155mm M795 (IMX-101)	V	V	IV*	V**	PASS	PASS

\* Passed original BI Test with one bullet through supp. charge, but failed (Type IV) with new test criteria of 3 bullets through supp. charge

\*\* Main charge targeted

- IMX-101 qualified as an main fill explosive in Feb, 2010
- Achieved type qualification for the 155mm M795 projectiles in June, 2010

# IMX-101 – Superior IM Performance



**BULLET IMPACT (TYPE IV)**



**FAST HEATING (TYPE V)**



**SYMPATHETIC DETONATION (PASS)**



**SHAPED CHARGE JET IMPACT (PASS)**

*Photos courtesy of PM-CAS*

# A Family of Insensitive Melt Cast Explosive Formulations

Insensitive Melt Cast Explosives manufactured at Holston Army Ammunition Plant

Formulation	Key Ingredients	Purpose	Qualification Status
IMX-101	DNAN + NTO + NQ	TNT replacement (for Artillery and other large caliber munitions)	Material qualified; Type qualified for 155mm M795, on-going for 155mm M1122 and 105mm projectiles
IMX-104	DNAN + NTO + RDX	Comp B replacement (for mortar applications)	Material qualified; Type qualification on-going for 81mm mortar, 60mm & 120mm to follow
PAX-48	DNAN + NTO + HMX	Comp B replacement (for mortar & tank ammunition)	Material qualified; Type qualification achieved for 120mm IM HE-T tracer round (NAMMO)
OSX-12	DNAN + NTO + RDX + Al	PAX-28 replacement (high blast applications)	Material under evaluation
PAX-21	DNAN + RDX + AP + MNA	Main fill for the 60mm M768 Mortar Rounds	Currently in-use in theater
PAX-41	DNAN + RDX + MNA	Main fill for the Spider Grenade	Currently in-use in theater

# Recent Manufacturing Achievement

- Current batch size over 1200 lb. (~1500 lb. possible)
- Over 660,000 lb. manufactured at HSAAP to date (over 550 batches)
- Utilize existing equipment in the melt-pour explosive facility
- Robust and repeatable processes established for IMX-101, and the raw ingredients (DNAN, NTO, NQ)
- Optimization opportunities identified to reduce process cycle time & to improve process efficiency
- Modernized explosive manufacturing facility to be commissioned in Q4 2012



# IMX-101 Process Improvement & Optimization Overview

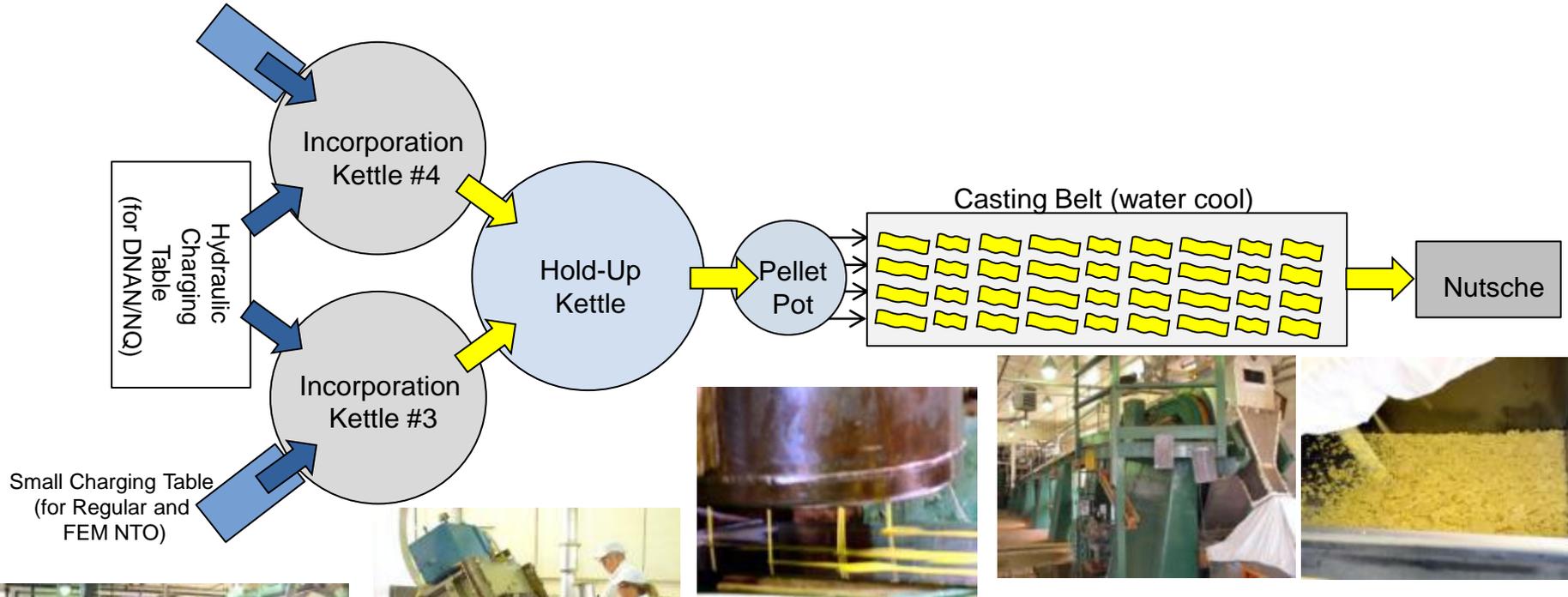
- Objective: To maximize the manufacturing process efficiency of IMX-101 in order to lower unit cost while maintaining the desirable properties
  - Reduced cycle time
  - Improved product consistency
- Potential time saving measures identified through an internal Lean Six Sigma Black Belt project and presented to the IPT
- Implemented agreed optimization changes in a special IMX-101 manufacturing campaign
- Final products from optimized process underwent Conformity and First Article Testing to validate product quality



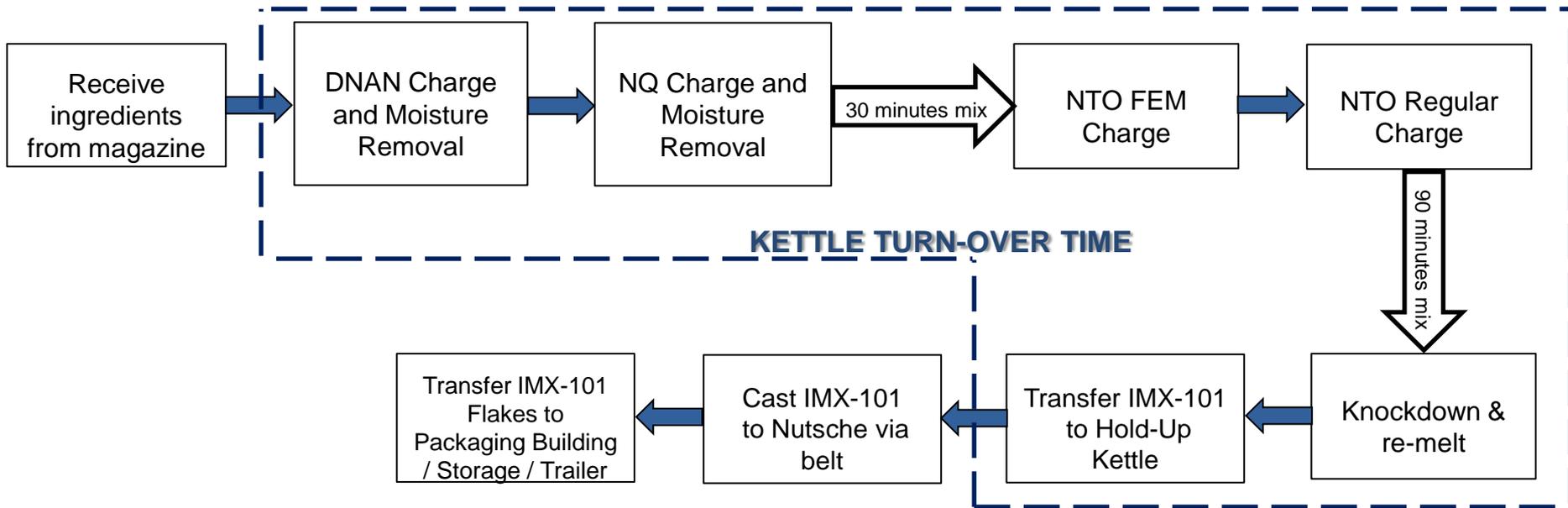
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# Current IMX-101 Manufacturing Process (1)



# Current IMX-101 Manufacturing Process (2)

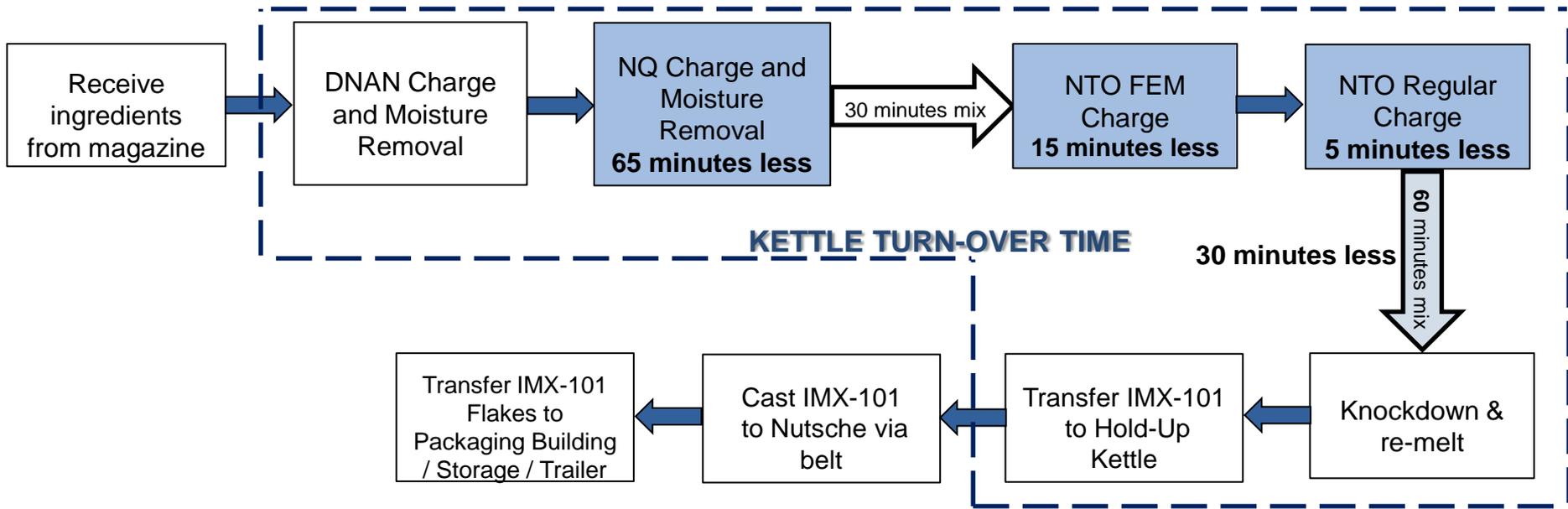


- Kettle Turn-Over time (from DNAN Charge to Removal of IMX-101 from Incorporation Kettle) ~ 415 minutes (6 hours 55 minutes)
- Once IMX-101 is removed from Incorporation Kettle, DNAN charge can commence for the next batch
- Three / Four batches (1207 lb) per 24 hours period
- Cannot satisfy future IMX-101 production requirement

# Kettle Turn-Over Time Reduction Opportunities

- The current Kettle Turn-Over Time of 7 hours is excessive
- Areas identified for optimization relating to kettle turn-over time reduction:
  - NQ charging time reduction
  - NTO FEM and NTO regular charging time reduction
  - Final incorporation time reduction
  - Use of alternate vessel for melting DNAN (time consuming step in incorporation kettle)
    - DNAN Pre-Melter concept (Modernized Facility)
- Materials made from the optimized process must satisfy all FAT requirements (5 consecutive batches)
  - Impact & Friction Sensitivity, VTS; ELSGT (composite sample of 5 batches)

# Optimized IMX-101 Manufacturing Process (1)

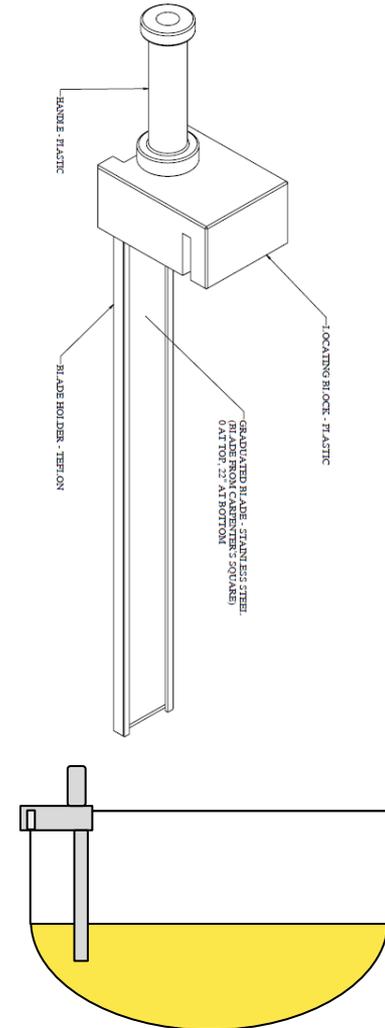


- Kettle Turn-Over time (from DNAN Charge to Removal of IMX-101 from Incorporation Kettle) ~ 300 minutes (from 415 minutes)
- Reduction of 115 minutes (1 hours 55 minutes) over current process
- Six/Seven batches (1207 lb) per 24 hours period possible
- Potential batch size increase to 1448 lb.
  - Design engineer confirms kettle capacity

# Optimized IMX-101 Manufacturing Process (2)

- DNAN level checking
  - Level gauge enables the DNAN levels (composition) to be more consistent
  - Previously, the required level of DNAN was calibrated in the PAX-21 production campaign
  - Consistent DNAN compositions also improved consistency of NTO and NQ compositions
    - Mean values closer to nominal targets, lower SD (less variance) and higher process capability (Cpk value)

Nominal Composition	Sample Size	Mean	SD	Cpk
DNAN (43.5%)	Previous 86 batches	43.034	1.228	0.490
	Optimized Process (8 batches)	43.338	0.529	0.987
NQ (36.8%)	Previous 86 batches	37.772	1.145	0.390
	Optimized Process (8 batches)	37.000	0.504	1.030
NTO (19.7%)	Previous 86 batches	19.249	0.648	0.875
	Optimized Process (8 batches)	19.962	0.472	1.307



# Optimized IMX-101 Manufacturing Process (3)

- Observations
  - Reduced kettle turn-over time did not compromise processability
    - Consistent efflux viscosity / flake homogeneity
  - Reduction in final mixing time did not result in settling
    - Consistent composition throughout casting operation
  - No change in IMX-101 flake appearance
- First Article Testing
  - 8 batches of IMX-101 manufactured, 5 consecutive subjected to FAT
  - All test requirements were met
  - Expanded Large Scale Gap Test:
    - 50% gap = 146 cards (62.5 kbar)
    - Comparable to baseline result
- Final Verdict
  - The optimized process was accepted

Batch	BAM Friction (N)	Naval Impact (cm)	VTS ml/g
IMX101-127	250.0	167.88	0.1
IMX101-128	265.2	164.82	0.03
IMX101-129	274.8	167.88	0.08
IMX101-130	279.6	171.00	0.11
IMX101-131	265.2	171.00	0.06
RDX Class 5 Std	162.9	21.13	N/A
Spec Limit	> RDX Class 5	< 150 cm	< 2ml/g

# Modernized Melt-Cast Explosive Manufacturing Facility

- Current Melt-Cast Facility (Bldg. L-4) at HSAAP will not meet future requirements of IM explosives
  - IMX-101, IMX-104, PAX-48, PAX-21, PAX-41
- IMX-101 optimized process will improve the current process efficiency at L-4
- Modernization of the Melt-Cast Facility will satisfy future production requirements
  - New design & technologies featured to further improve process efficiency
- Funded by the US Army Project Director Joint Services (PD-JS)
- Construction started: May 2011
- Scheduled completion date: Oct 2012



# Modernized Melt-Cast Explosive Manufacturing Facility

## Benefits / Improvements

- Annual production capacity increase > 250%
  - DNAN Pre-melter concept to streamline process
  - Growth opportunity with other IM products
- Replacing aging equipment with state-of-the-art systems
  - New flaker belt design eliminates water exposure
  - New discharge valve with better flow control
- Better control of temperature profile in melt kettle
  - Improve process and product consistency
- Accurate material balance resulting in consistent product composition
  - Load cell in kettle to ensure accurate ingredient increment



# Modernized Melt-Cast Explosive Manufacturing Facility

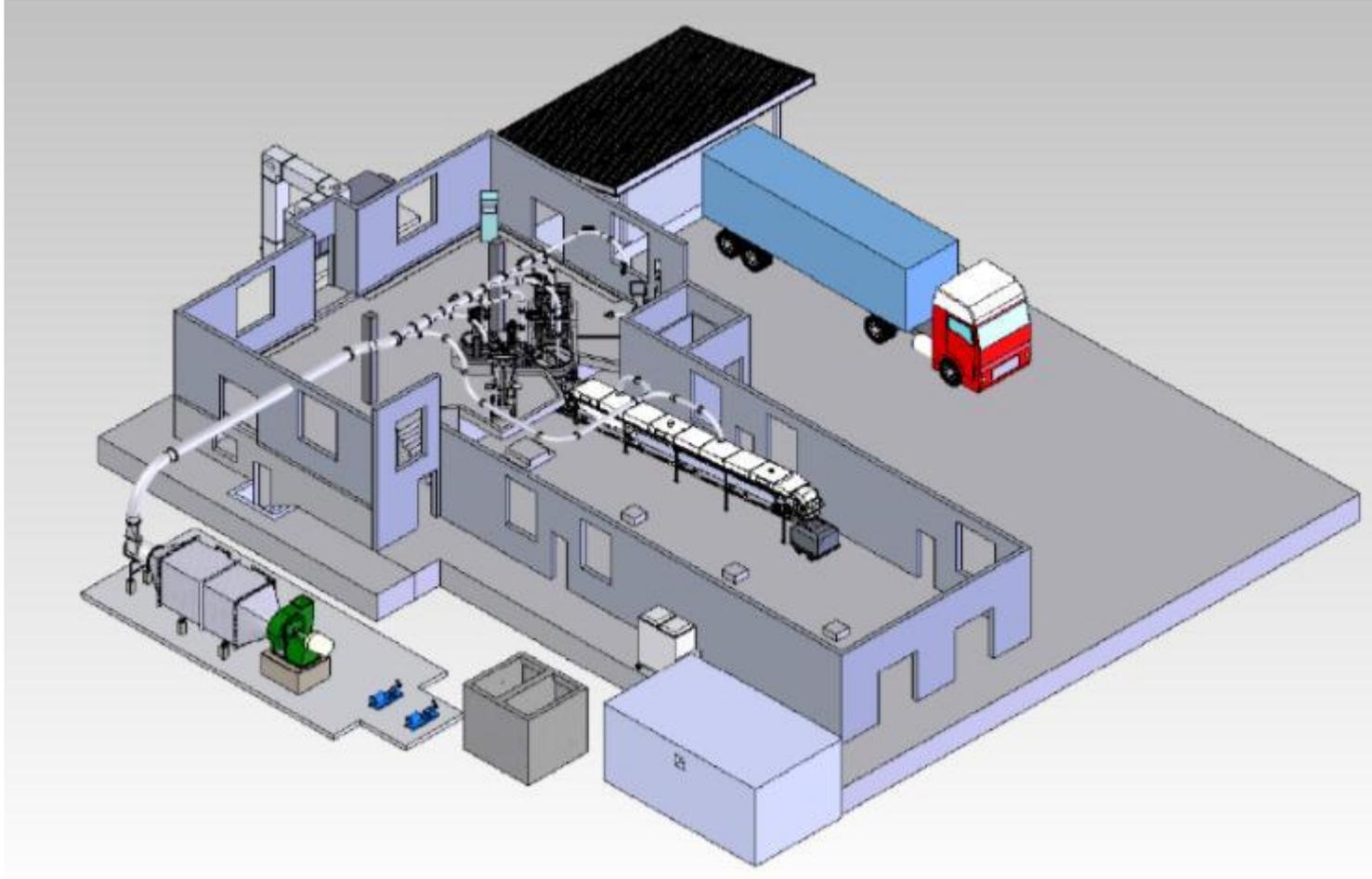
- DNAN Pre-melter
  - Currently, DNAN melting and moisture removal takes almost 2 hours in the incorporation kettle
    - The optimized process did not address the reduction in DNAN melting time
  - Similar to the Comp B process (TNT melter), use of alternate vessel for DNAN melting and moisture removal will free up the incorporation kettle



**DNAN Pre-Melter**

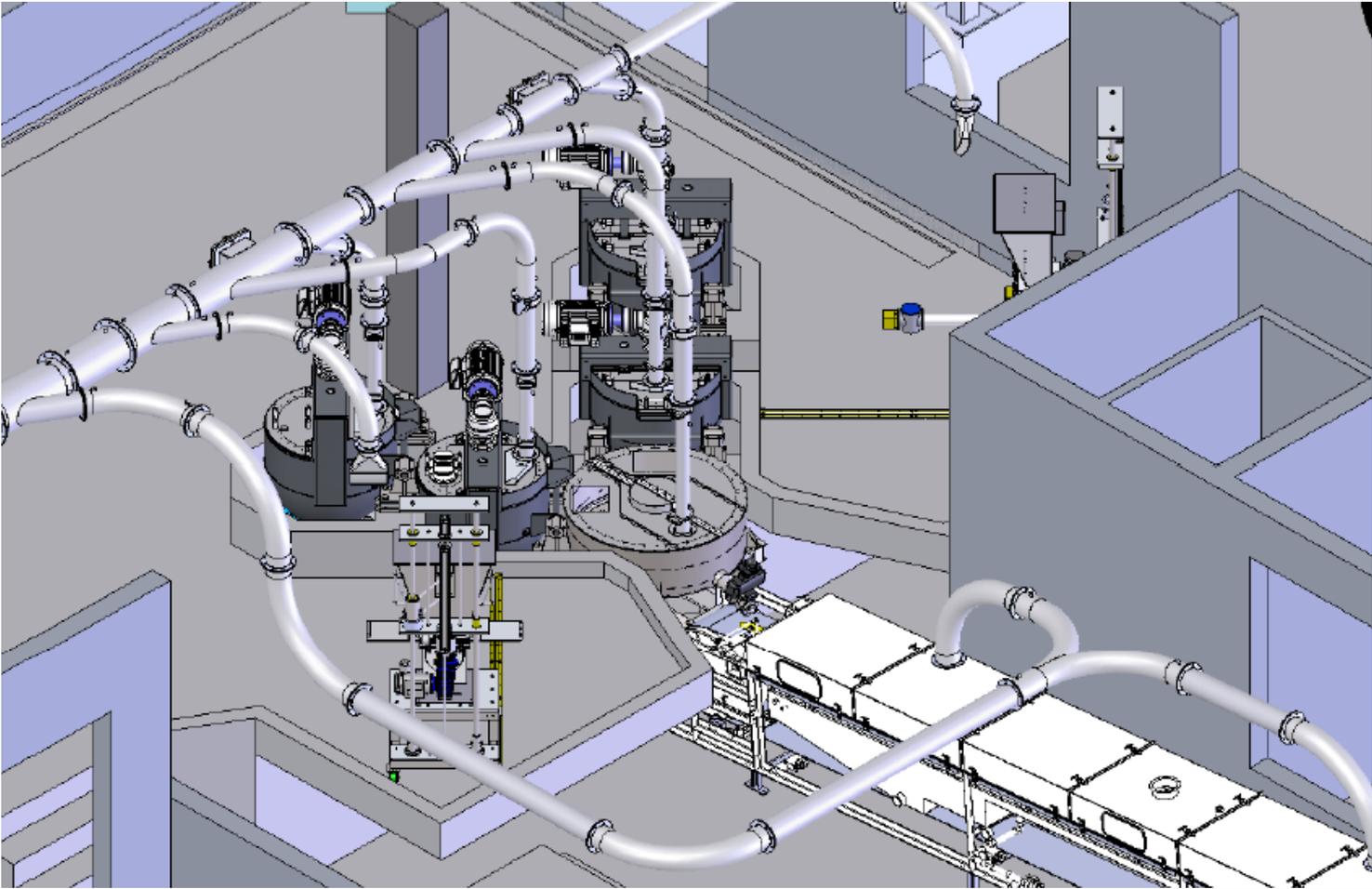
# Modernized Melt-Cast Explosive Manufacturing Facility

- Building Layout



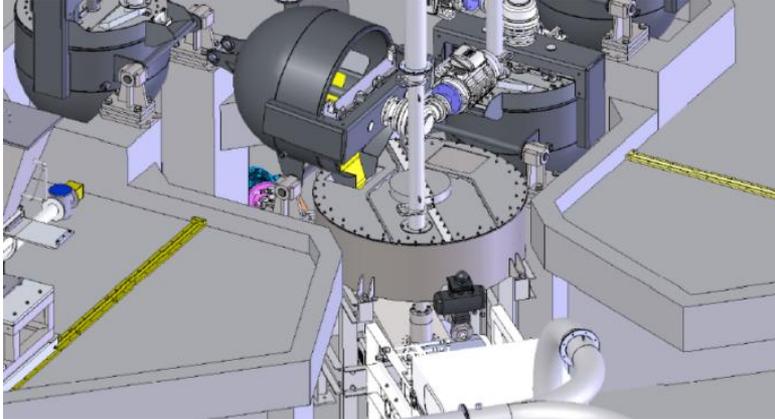
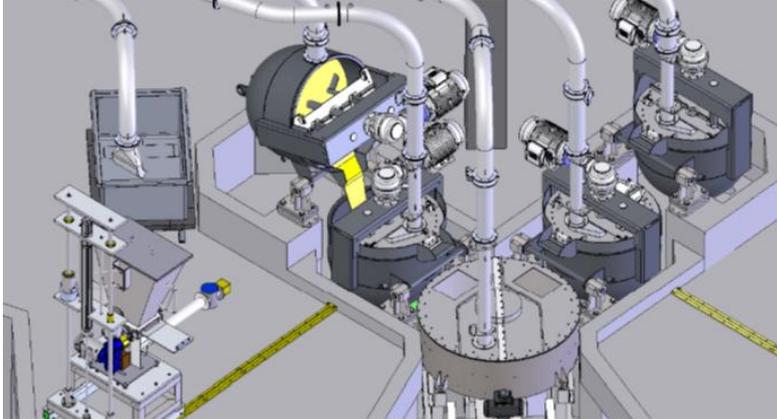
# Modernized Melt-Cast Explosive Manufacturing Facility

- Equipment Layout

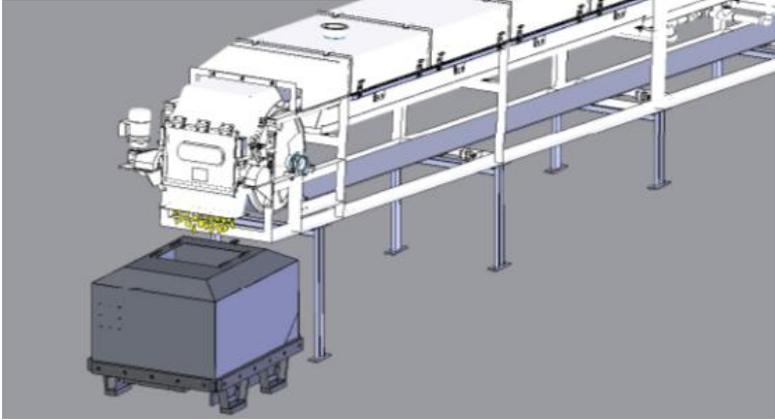
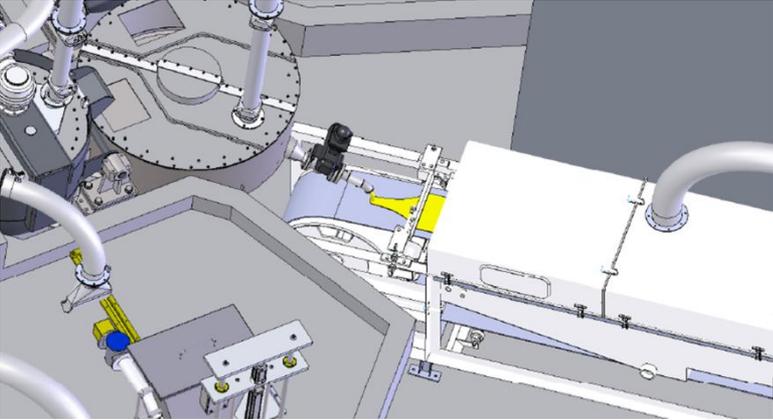


# Modernized Melt-Cast Explosive Manufacturing Facility

- Ingredient Incorporation



- Product Casting



## Concluding Remarks

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- Robust large scale manufacturing process for IMX-101
- Urgent need for process optimization due to higher demands
- 30% reduction in Kettle Turn-Over Time achieved (reduced unit cost)
- Improved process efficiency (six 1200 lb. batches per day currently)
- No significant difference observed from analytical results (all batches passed all spec requirements)
- More consistent composition results with the use of the DNAN level checker
- Modernized Melt-Cast Explosive Manufacturing Facility shall further enhance HSAAP capability and capacity as the center of excellence in IM explosive manufacturing
  - Improved product quality
  - Improved process efficiency

# Acknowledgement

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